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Managing uncertainty in the assessment of hydrological impacts of climate change

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KIC Water Workshop

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Global water resource challenges

Some current global issues:

- 900 million lack access to clean drinking water
- 1.4-2.1 billion live in water stressed areas
- unsustainable use of water – declining groundwater levels, dry rivers
- increasing competition for water resources – at local, regional and international scales
- degradation of water quality – from over-abstraction and pollution

And in the future

- increased demand – population growth, economic development, agriculture
- climate change - 6 billion in water-scarce areas by 2050?

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Climate change impacts

We confidently expect:

- Intensification of hydrological cycle – increased floods and droughts
- Changes to global distribution of precipitation – increased rainfall in high latitudes, decreases in tropics

But:

- Global Climate Models are very poor at representing rainfall
- Regional and local effects are highly uncertain

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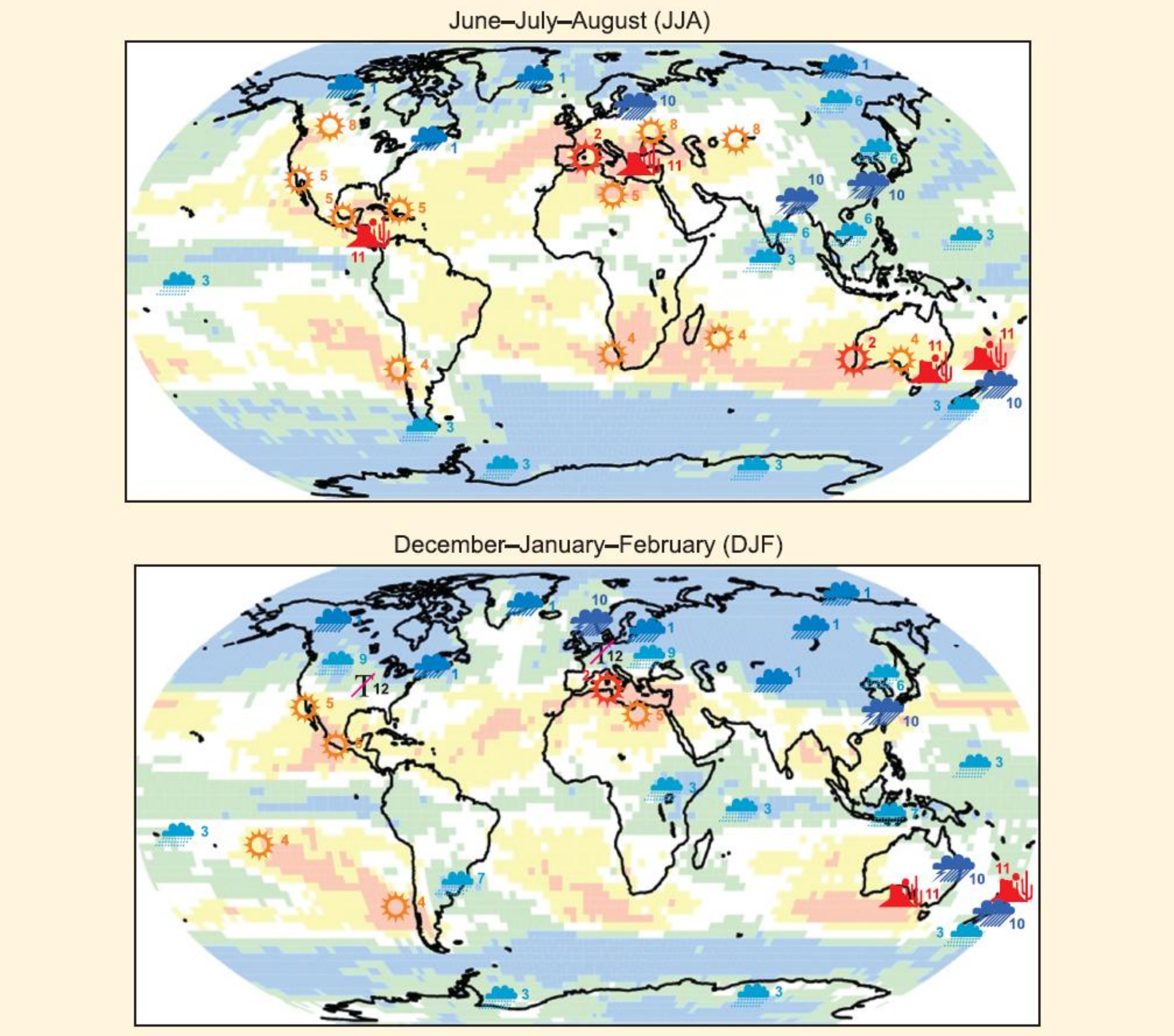
Precipitation change by 2080-2099

21 GCM model ensemble
Red – precipitation decrease very likely
Blue - precipitation increase very likely
White – disagreement about *sign* of precipitation change
(after IPCC 2007)



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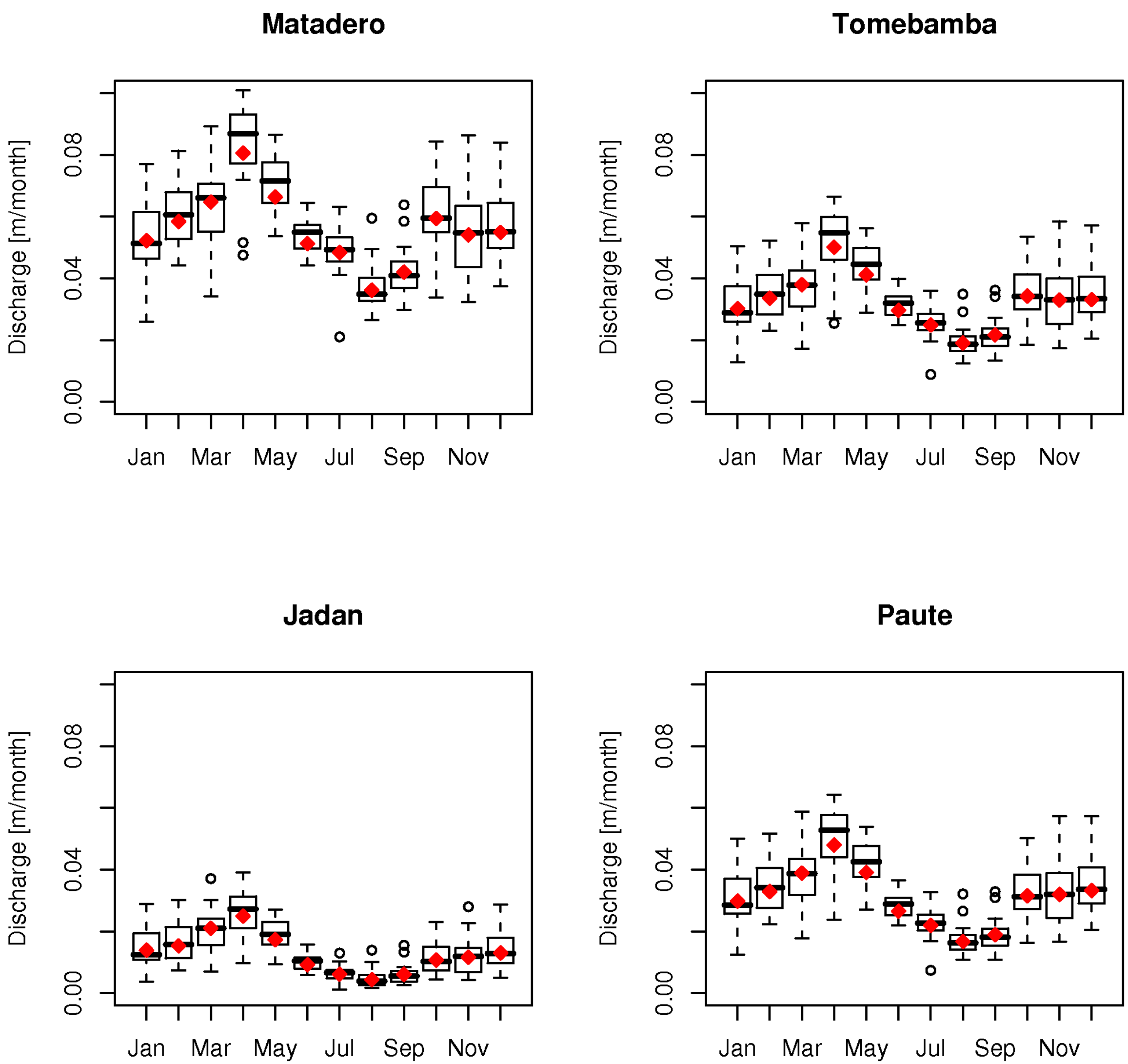
Predicted change in Ecuador rivers

Paute Basin
S Ecuador Andes

2011-2030 flow range from IPCC GCM ensemble

Red – mean observed (after Buytaert, 2009)



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The way forward.....

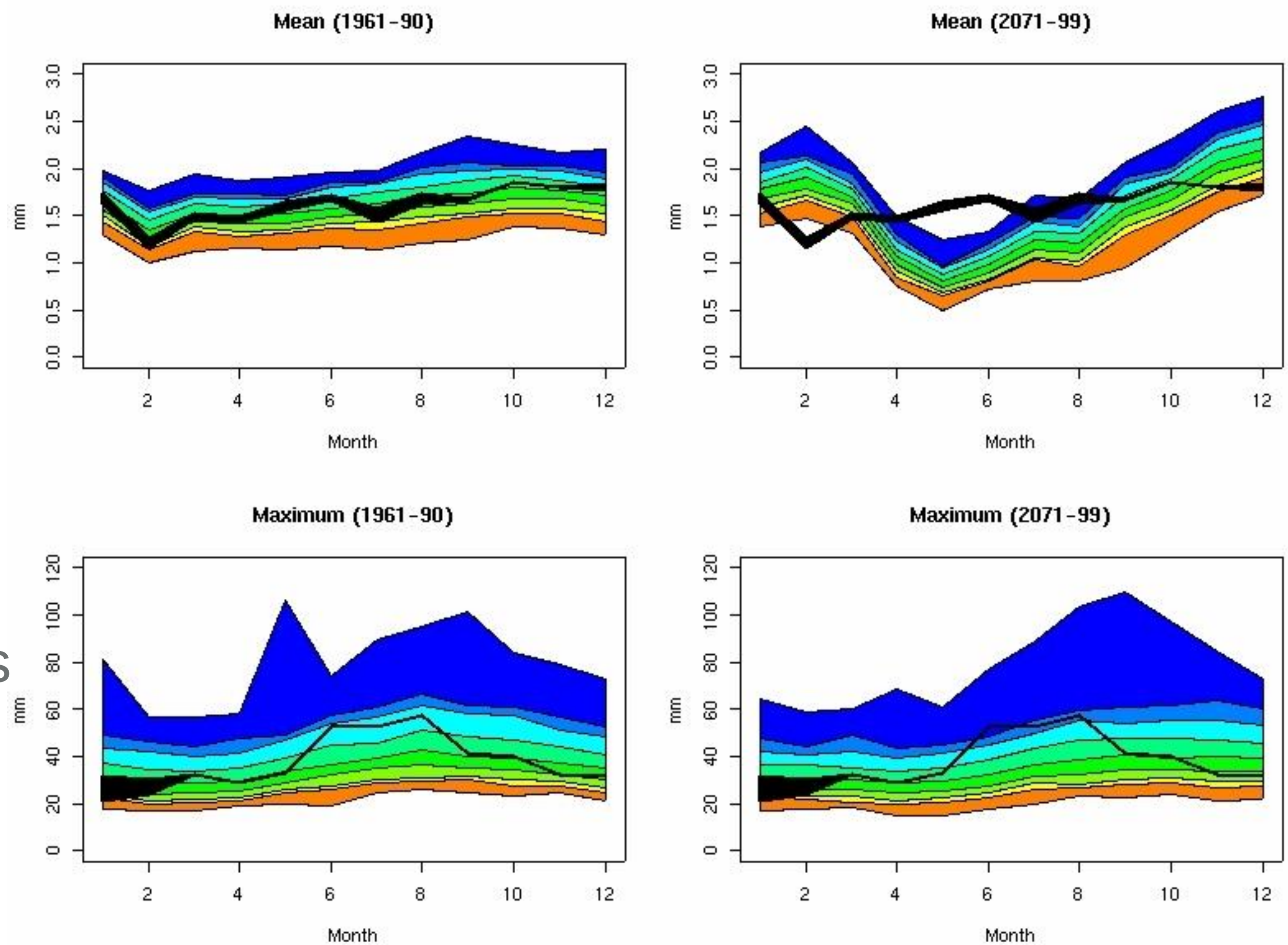
- Improved global and regional climate models

  - but with recognition of limits to predictability
- More intelligent use of climate models

  - e.g. new generation statistical downscaling methods for precipitation and evaporation based on analysis of reliable GCM outputs
- Adaptation solutions that are robust in the face of (large) uncertainty

GLM simulated rainfall, Heathrow

Monthly properties of daily rainfall 1961-1999 and 2071-2099 compared with observed values (in black)



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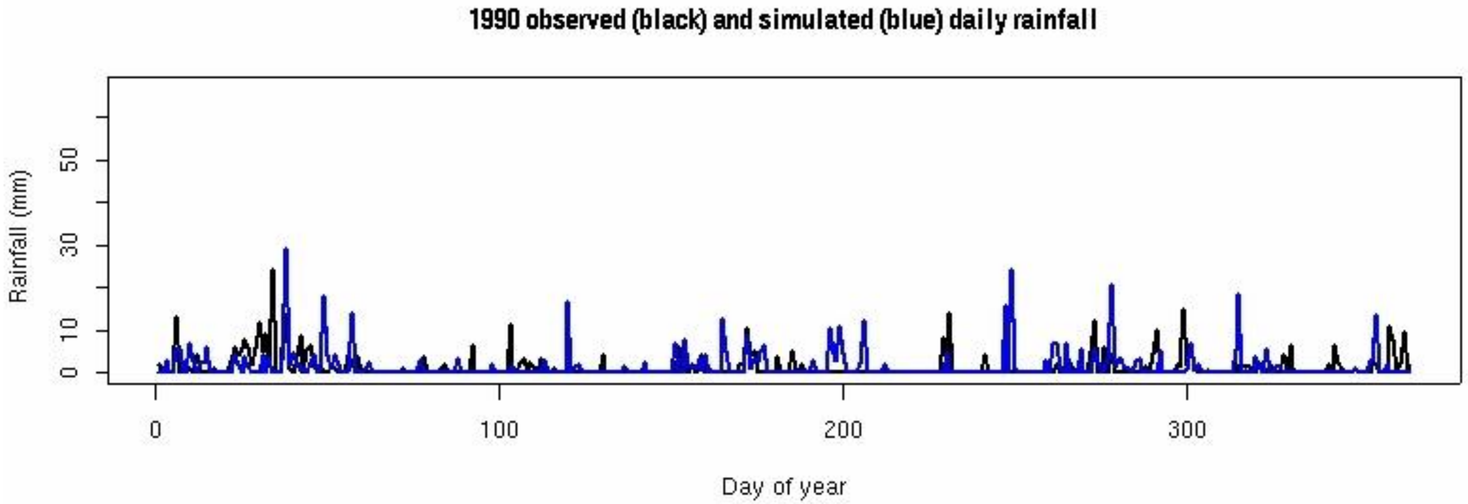
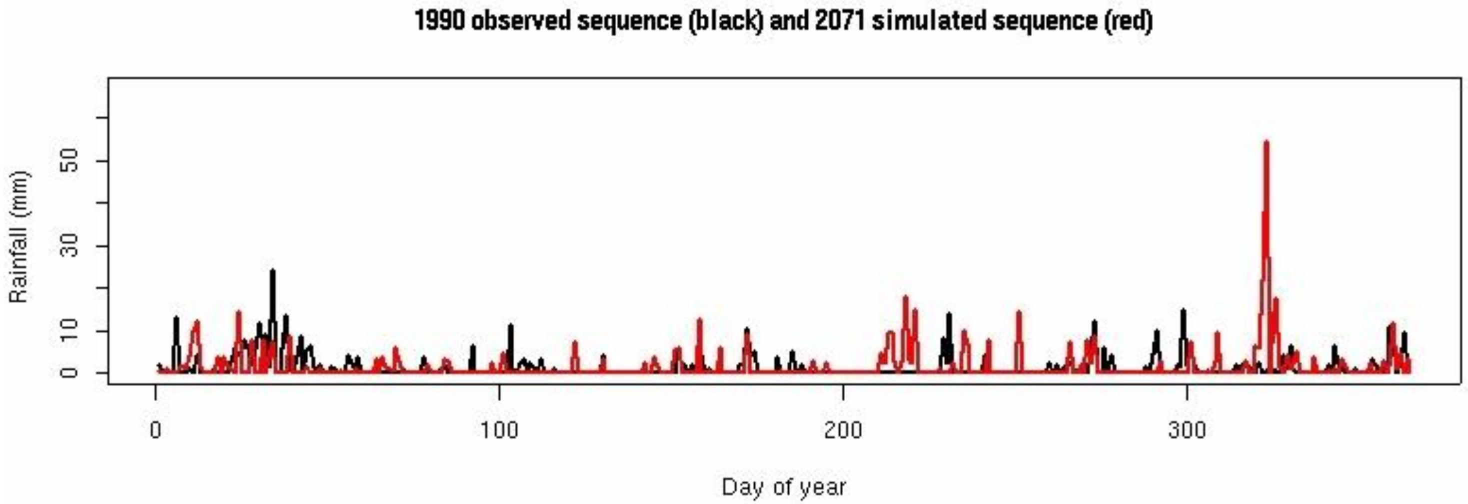
Heathrow daily rainfall 1990 & 2071

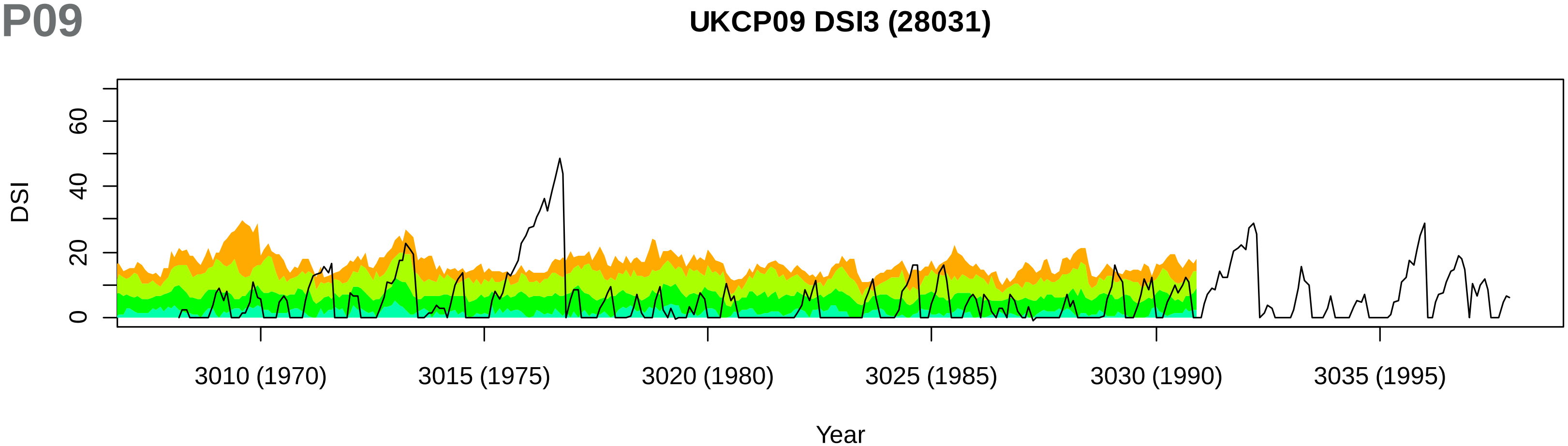
blue 1990
red 2071
black - 1990 observed



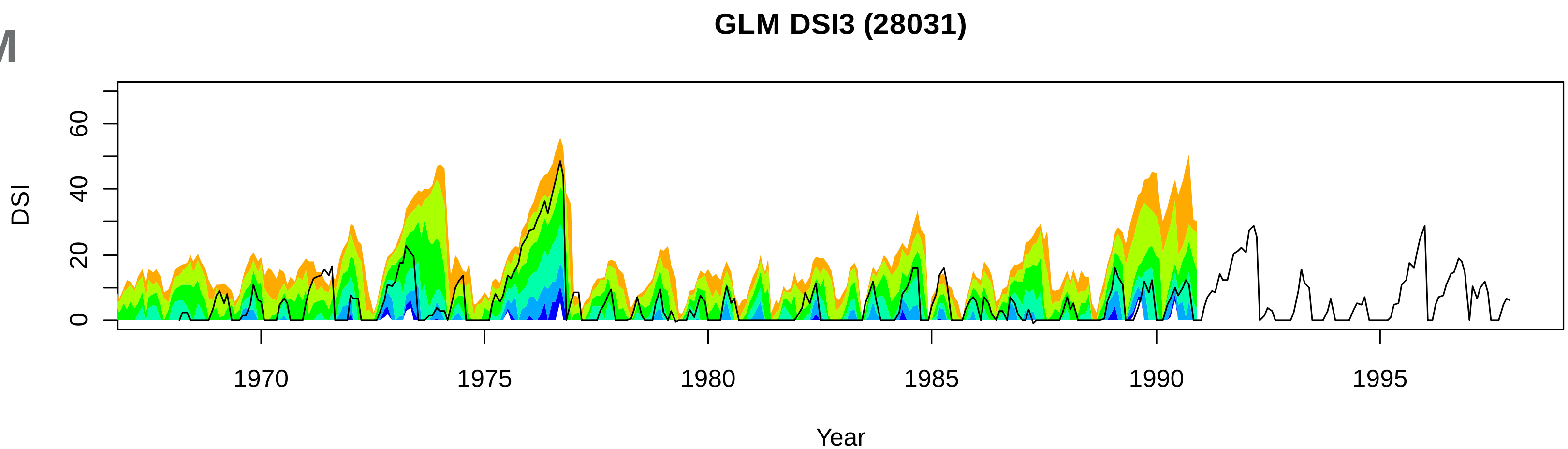


Downscaling drought

UKCP09



GLM



Solid line – observed 3 month drought Index
Colour – simulated probability distribution

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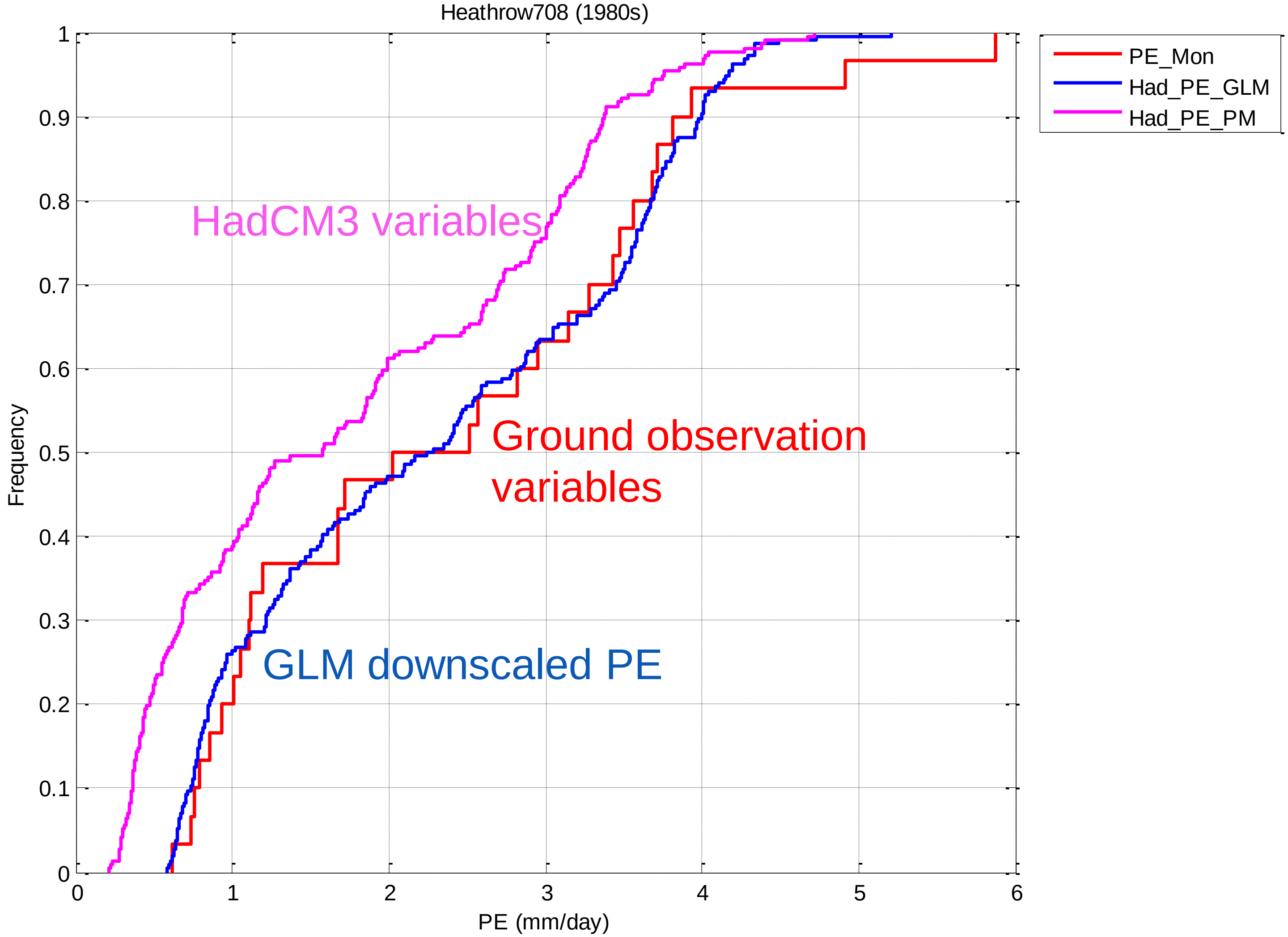
PE downscaling (Penman-Monteith)

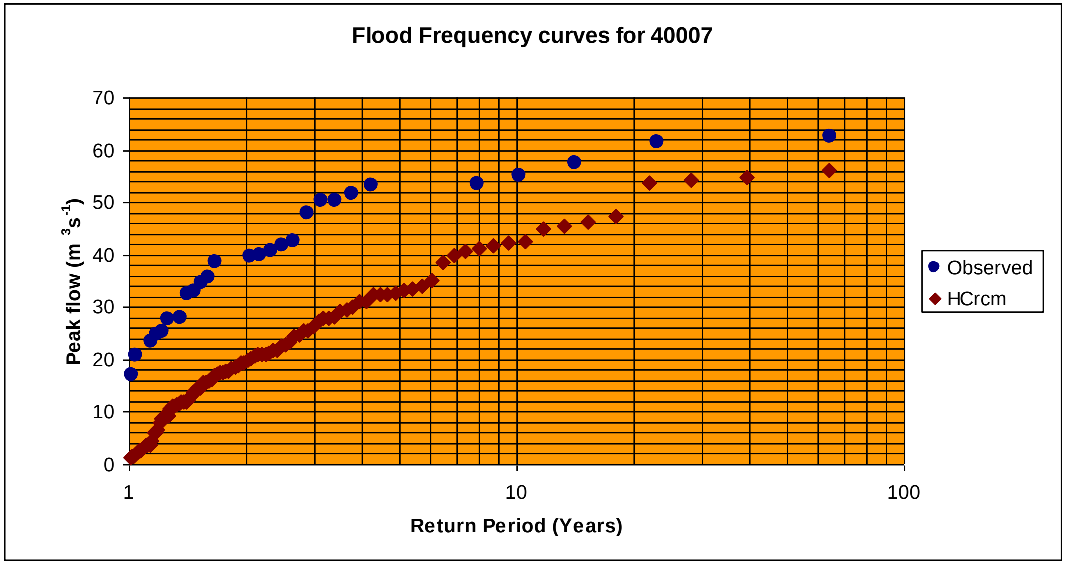


Assessment of climate change impacts

- A large number of studies have been reported that take GCM/RCM outputs, with downscaling, applied to hydrological impact assessment
- Results are often complex, dependent on regional climate variability and catchment-specific response, hence adaptation response needs to take into account local detail
- Implications for flood and water resources management can be large – consider examples from the UK and Southern Africa….

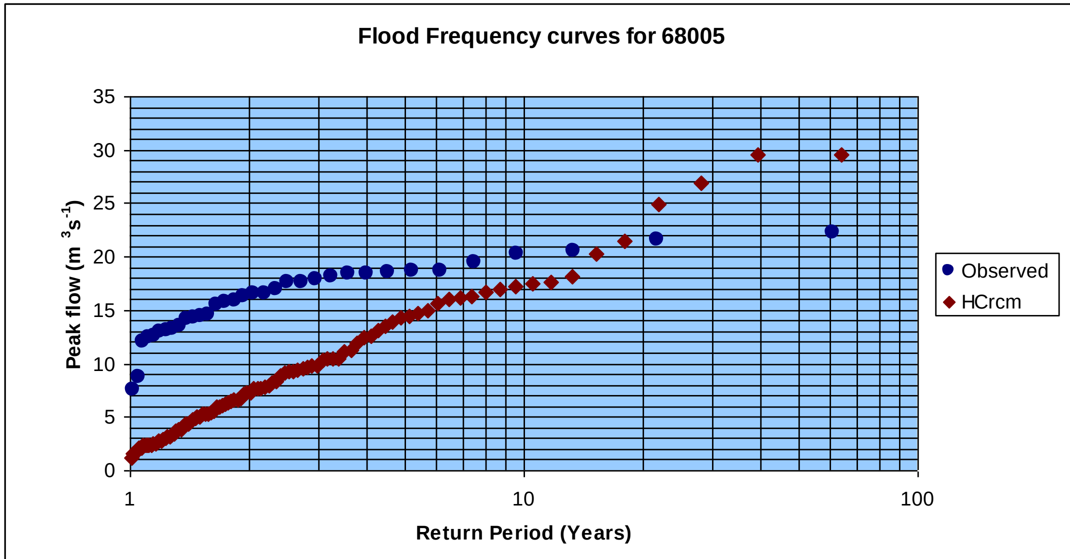
UK flood frequency changes 2080s

Medway, SE England



Hadley Centre RCM
GLM disaggregation
Red-current
Blue-2080s

Weaver, NW England



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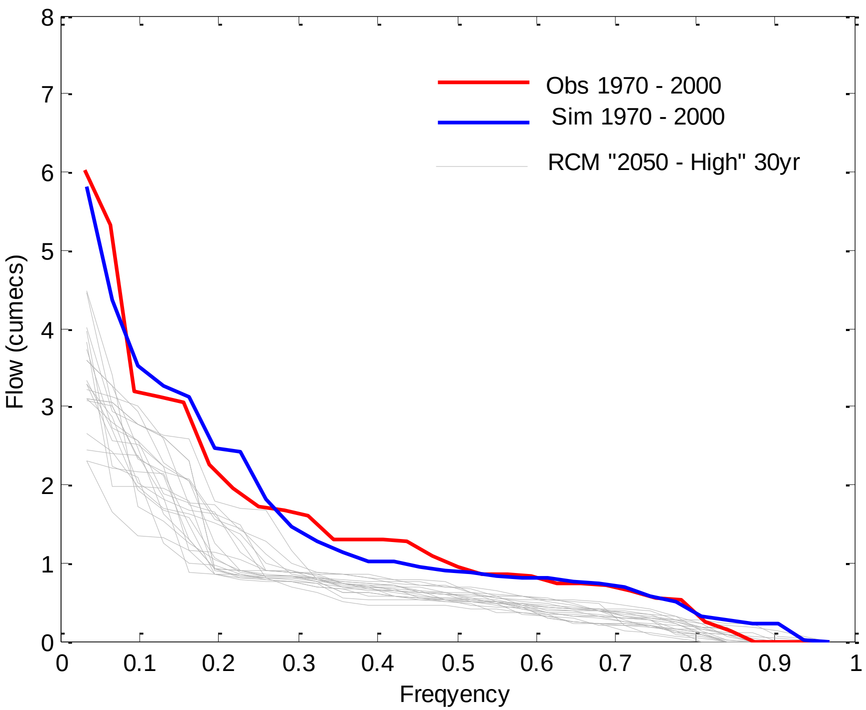
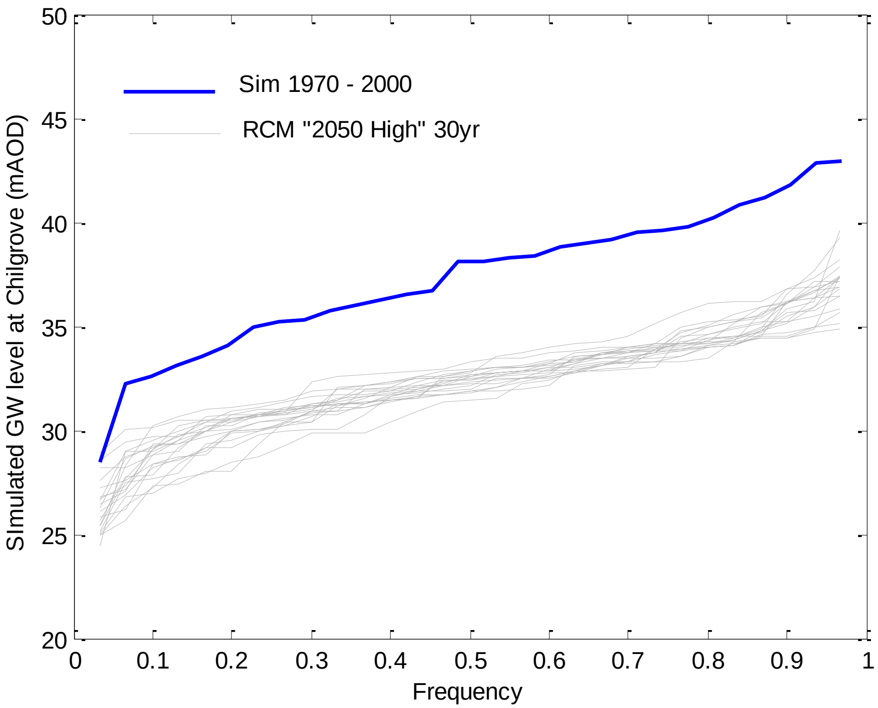
S England chalk groundwater 2050s

River Lavant flows



Groundwater levels



after Butler, 2009

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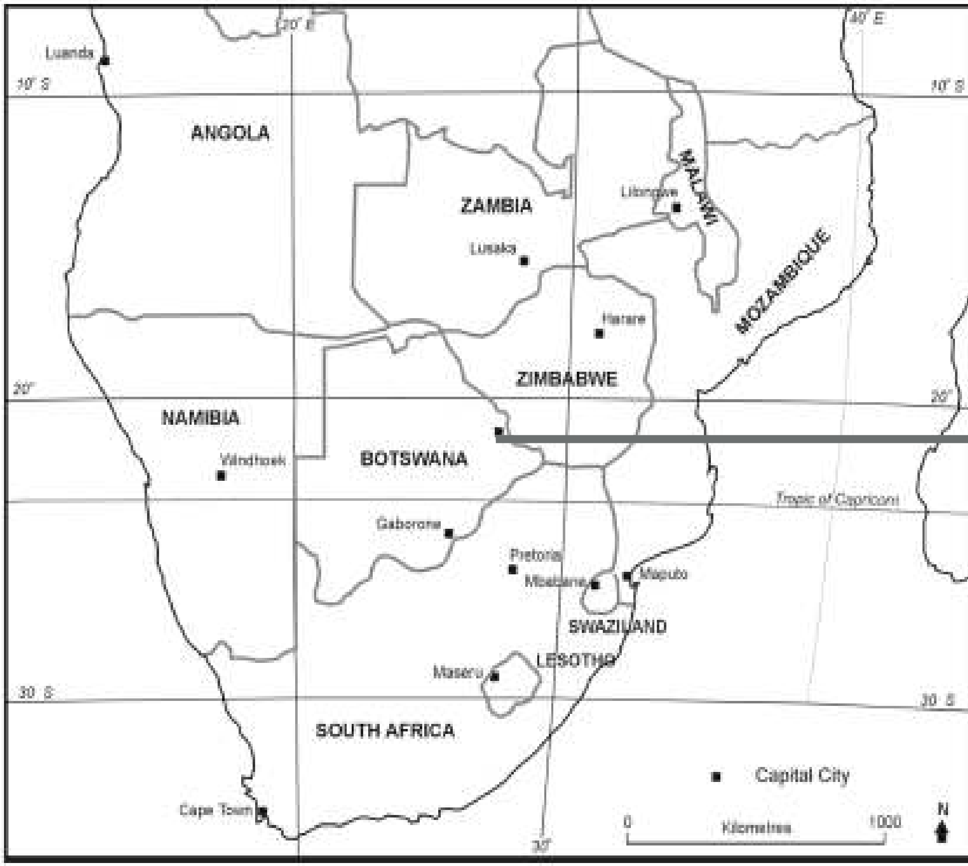
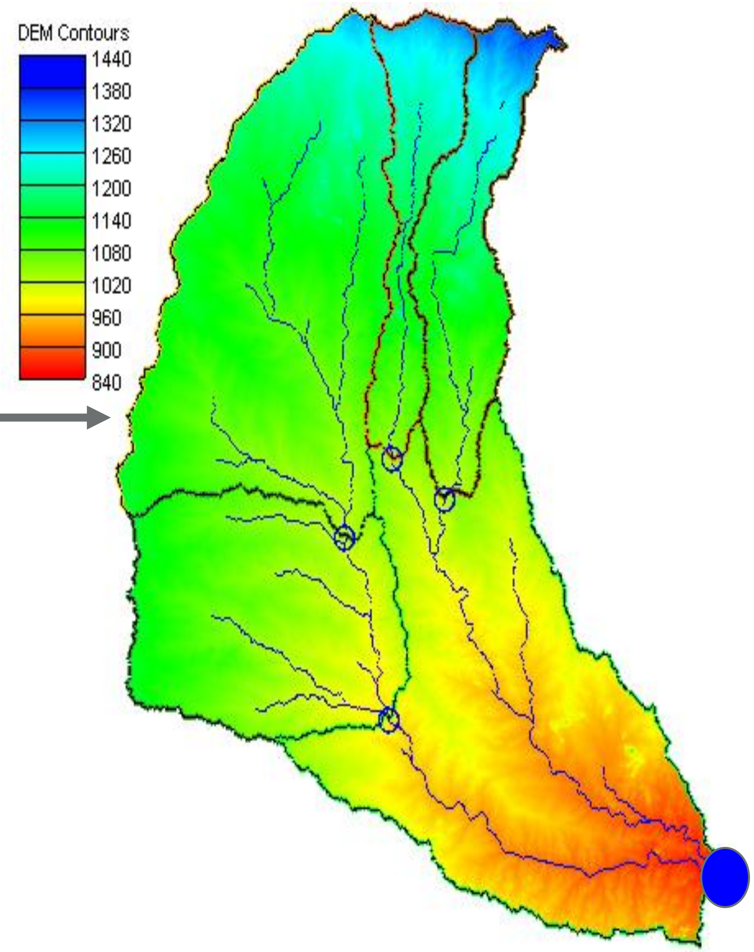
Proposed dam, Gabarone, Botswana

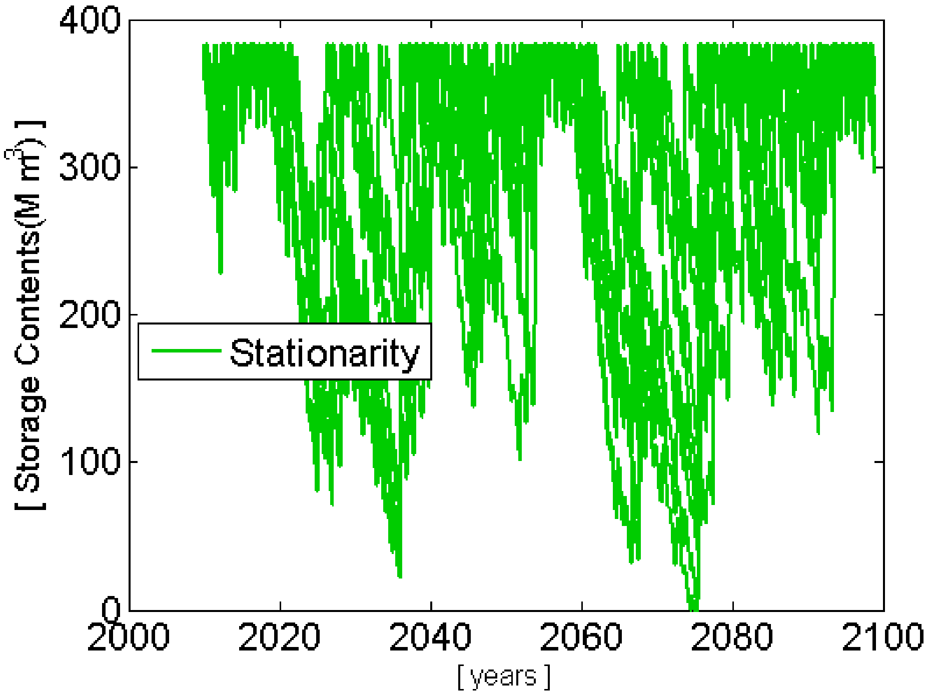




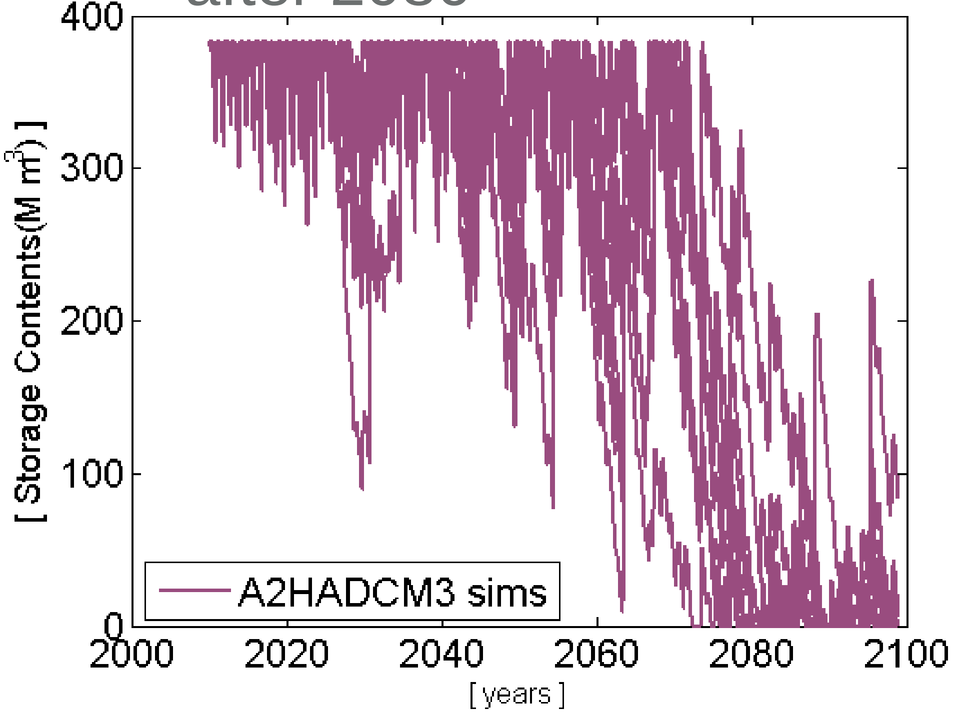
Proposed dam

Botswana: Gabarone dam performance

Stationary climate



HadCM3 A2 simulation
Reservoir never full
after 2080



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Science needs for impacts assessment

- Most impacts analyses are based on future climate applied to models of today's environment
- There is a pressing need to develop an integrated science base to support analysis of non-stationarity
  – how will climate change affect interactions between vegetation, soils, hydrological processes, biogeochemical cycles, ecosystem function?
- Scientists (and their funders) need to break down interdisciplinary barriers

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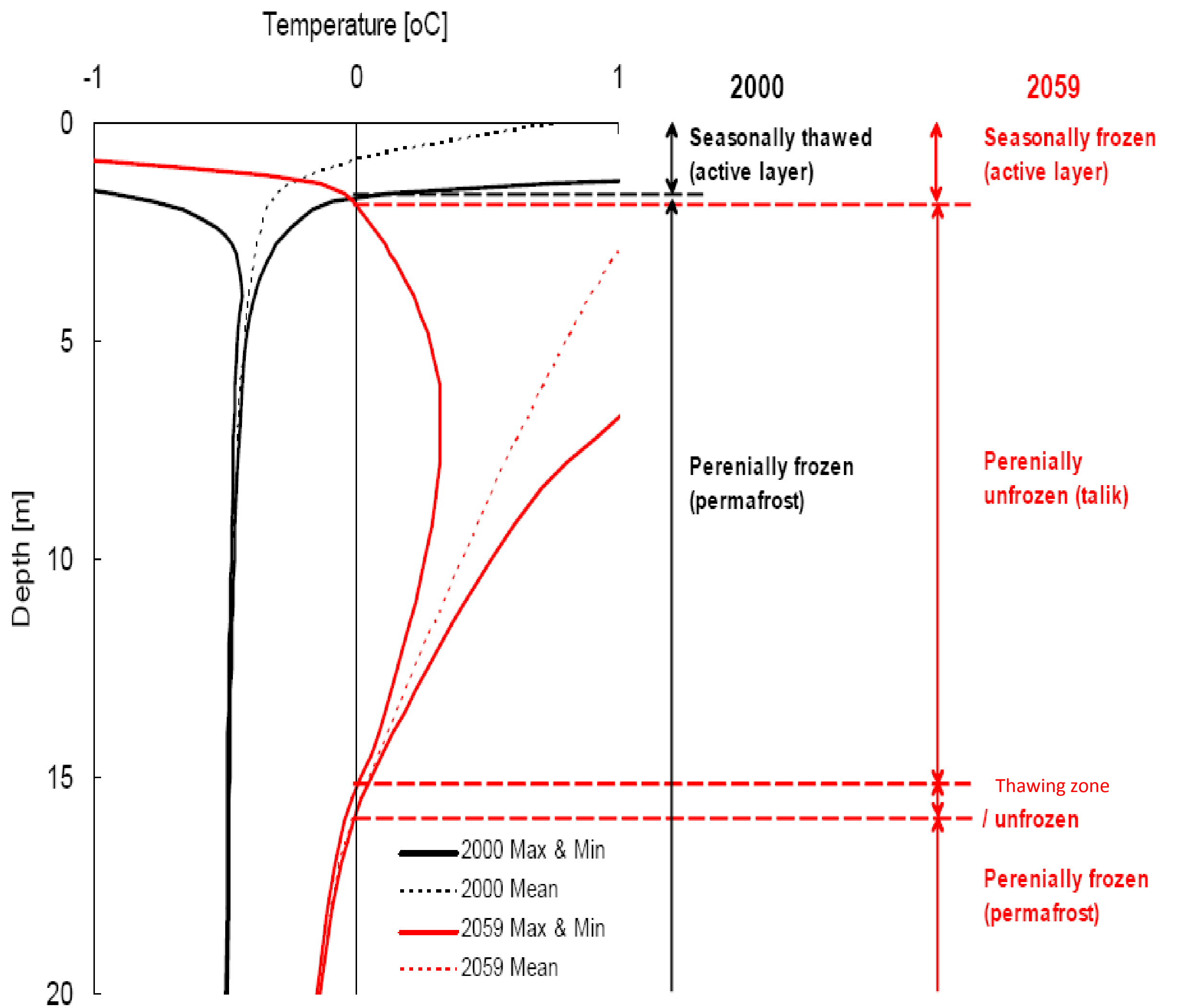
Climate change - Siberian permafrost

Soil temperature simulated profiles
2000 Black
2050 Red

After Nishimura et al.



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From scenario to vulnerability analysis

Most analyses are scenario specific

It is generally accepted that ensembles of climate mode results are required to scope uncertainty, but these:

- do not scope the true uncertainty
- offer limited insight into vulnerability
- are rapidly out-dated

New approaches are beginning to address vulnerability analysis

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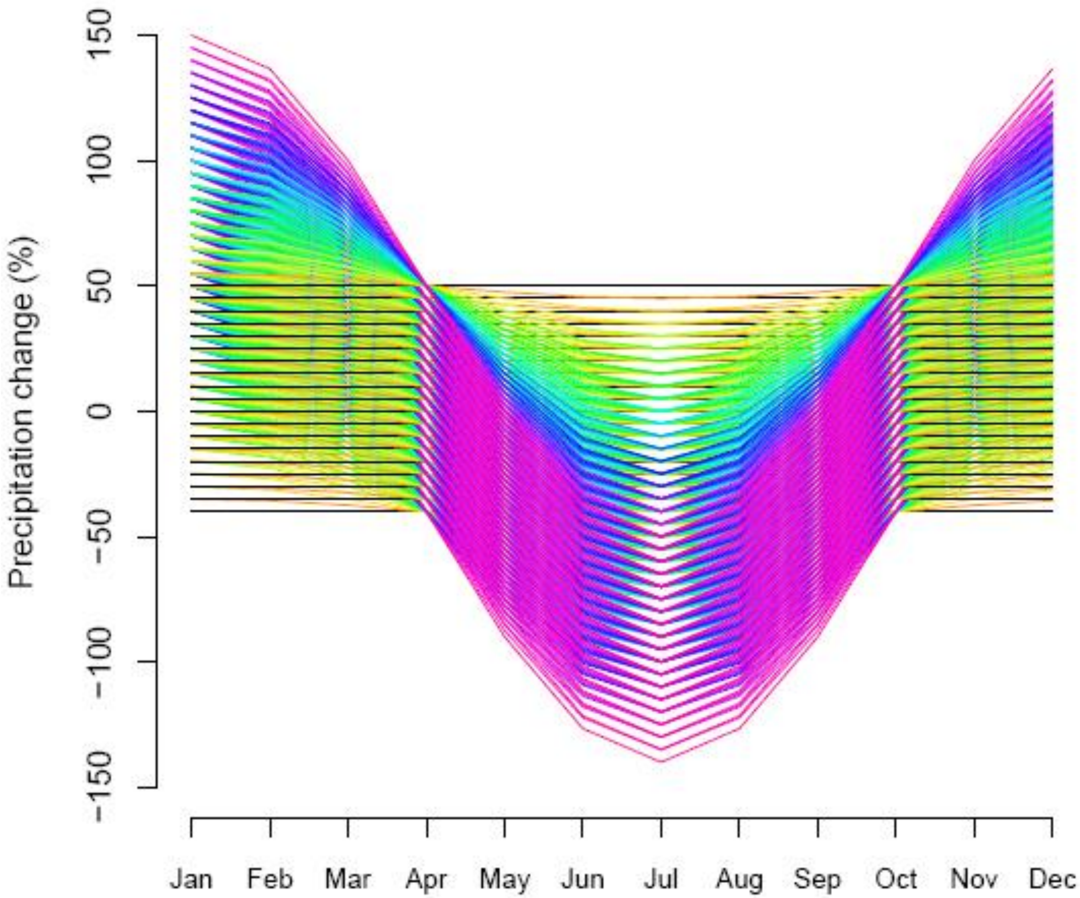
Analysis of UK precipitation change

GCM/RCM scenario classification- change in
a) mean
b) seasonal variability



After Reynard, 2009

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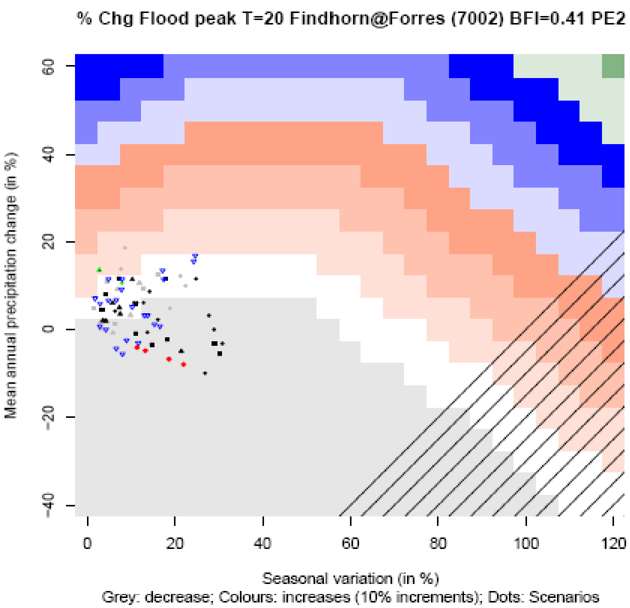
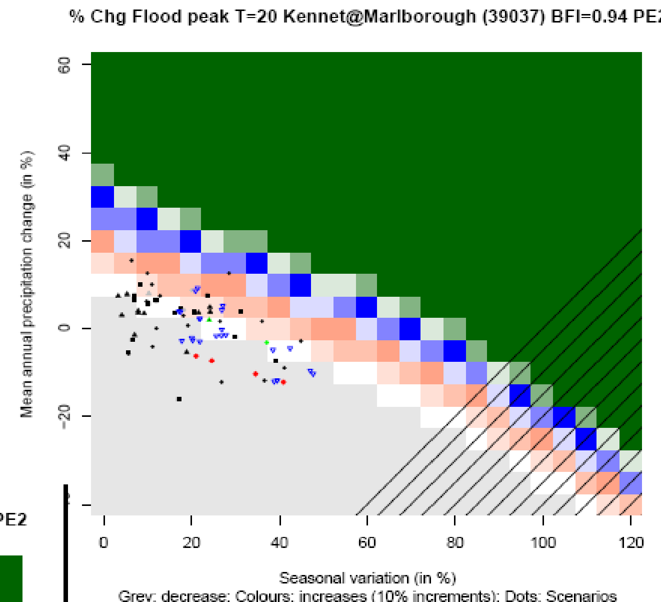
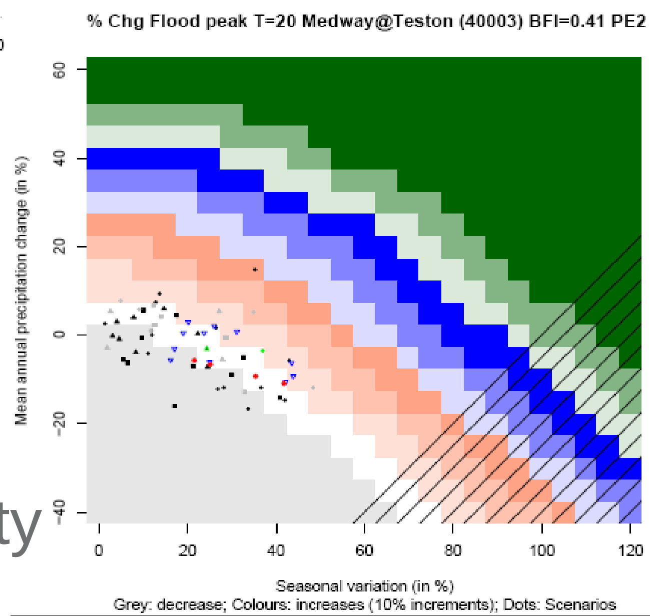
20 year flood vulnerability



Three types of catchment vulnerability





Vertical axis - Change in mean precipitation
Horizontal axis - Change in seasonality

Colours represent 10% changes
Dots represent GCM/RCM scenarios

Adaptation to climate change

Technical solutions depend on societal response, e.g.

- the mitigation agenda (and hence climate futures)
- behavioural response to climate change (from changing patterns of water use to population migration)
- response to policy instruments

And there is a need to:

- convince the public (and politicians) that climate change is real, but uncertain
- develop adaptation solutions that are robust in the face of uncertainty, adaptable, and consistent with the mitigation agenda

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Foresight analysis

UK experience has been that Foresight studies have been important in developing insights, defining the research agenda, developing awareness in the policy arena

The key is the development of plausible socio-economic scenarios, and the associated analysis of change

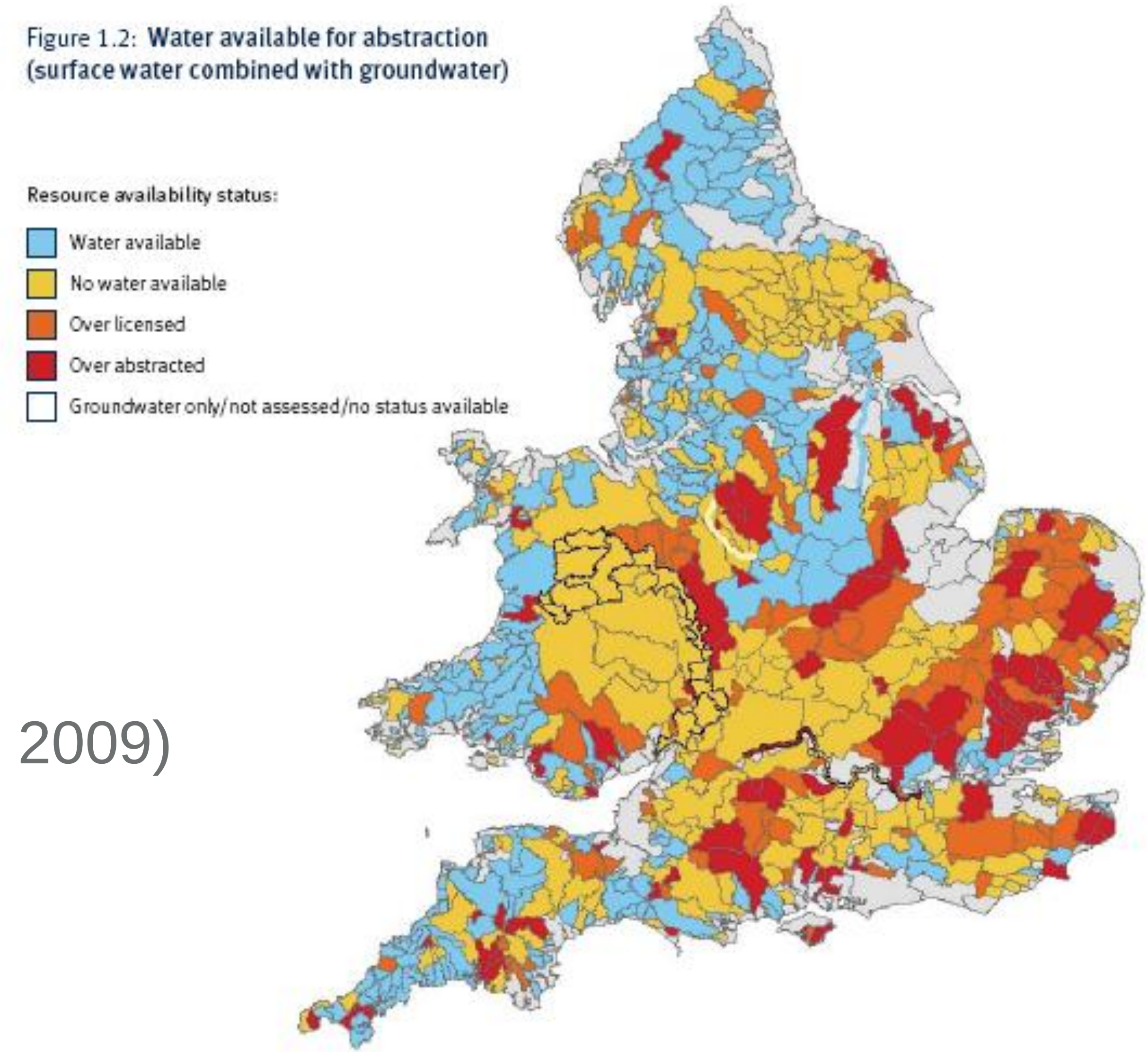
Foresight Future Flooding was influential in increasing the UK commitment to flood defence expenditure

A 2009 water resources foresight study has identified the issues, but not yet quantified the solutions

Water available now for abstraction

Blue
-water available
Orange
- over-licensed
Red
-over-abstracted

(Environment Agency, 2009)

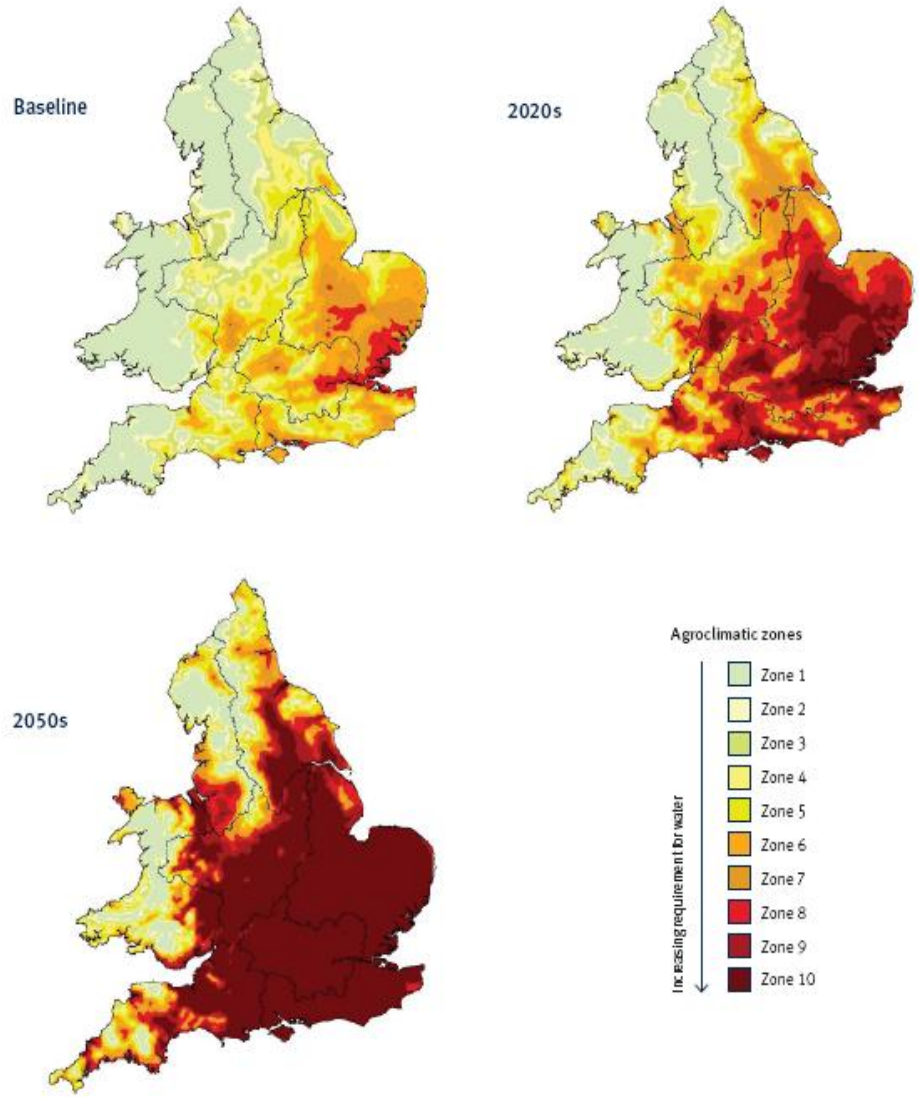


Changes in summer growing conditions

Agricultural summer conditions England and Wales

Present, 2020s, 2050s (Environment Agency, 2009)

Red – drought prone



Some UK water resource issues

- Existing resources are stressed, particularly in SE England
- Climate change will bring high regional and seasonal variability of impacts, but major reductions in summer flows are expected
- Upland water quality issues will emerge
- Diffuse pollution problems will increase
- Pressures on household demand will increase
- The role of agriculture is particularly uncertain, and 60% of embedded water is currently imported
- EU legislation will need to address ecosystem futures

Water futures

Water futures will require existing issues of resource scarcity to be confronted

Radical changes are likely to water management in water stressed areas

Innovative solutions will be required, as well as learning from the past

Adaptation will depend on clear and coherent policy across sectors – water, land , energy – and consistency with the mitigation agenda

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Old and new solutions - Oman

Rehabilitated falaj (qanat)

Modern recharge dam

The social dimension

Social response controls:

- the drivers of climate change
- the societal response to climate change
- environmental futures

Effective engagement with social science is needed to understand societal, economic, institutional and policy aspects, engage with stakeholders and provide appropriate policy guidance

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Working with stakeholders

Andean farmers, Ecuador

Water managers
DCDC Phoenix Arizona

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Concluding comments

- Climate futures will remain uncertain – improved predictions are needed, but adaptation solutions must be robust to uncertainty and flexible
- There are major challenges to develop the multi-disciplinary science to predict environmental change
- Holistic assessment of climate futures is needed – foresight is a useful tool
- While there are major technical challenges, the outstanding need for the natural science and engineering communities is to join a dialogue with the social scientists to address the social, economic, institutional and policy dimensions of climate change